A LITERATURE REVIEW ON VALUE STREAM MAPPING WITH A CASE STUDY OF APPLYING VALUE STREAM MAPPING ON RESEARCH PROCESS

A Thesis

by

XIAOQI LI

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	José L. Fernández-Solís
Committee Members,	Zofia K. Rybkowski
	John R. Peterson
Head of Department,	Joseph P. Horlen

May 2014

Major Subject: Construction Management

ABSTRACT

Value stream mapping is a lean manufacturing technique that originated from the Toyota Production System (TPS). It is used to analyze and design the flow of material and information required to bring a product or service to a consumer. This thesis has two main objectives. The first is an in-depth literature review on value stream mapping, especially concerning useful value stream mapping tools and the application of value stream mapping in construction industry. The literature review of value stream mapping provides an overview of this lean tool, which offers a framework for future study in the application of value stream mapping in construction industry. The other objective is to perform a case study of my own experience in doing this research study and the value stream mapping of my thesis writing process. The value stream mapping process helps visualize the work and target waste, which enables future improvement toward a better state. As a result, the improved value stream maps can be guidelines for future studies.

DEDICATION

To my beloved family, my committee board and friends, thank you for all of your support along the way.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr. José Fernández-Solís, and my committee members, Dr. Zofia Rybkowski and Dr. Russell Peterson, for their guidance help and support throughout this research.

Thanks to my friends, Chao Xiao, Di Ai, Moruf Jimoh and Jiaxing Li. Without their suggestions, my research progress wouldn't go so smoothly.

Thanks to my family who support me all the time, my beloved parents, my grandparents and my new baby cousin. It is their encouragement and supports that help me go through my master program.

NOMENCLATURE

Lean manufacturing	A production practice that considers the expenditure of resources for any goal other than the creation of value for the end customer to be wasteful, and thus a target for elimination. (Liker, 2004)
Value Stream	The sequence of activities required to design, produce, and deliver a good or service to a customer; includes the dual flows of information and material (Womack & Jones, 1996).
Value Stream Mapping (VSM)	A lean-management method for analyzing the current state and designing a future state for the series of events that take a product or service from its beginning through to the customer (Rother & Shook, 2003).
Push-Pull System	Describes the movement of a product or information between two subjects. In markets, consumers usually "pull" the goods or information they demand for their needs, while suppliers "push" them toward the consumers. Push production is based on forecast demand and pull production is based on actual or consumed demand. (Liker, 2004)
Just in Time (JIT)	A production strategy that strives to improve a business's

	return on investment by reducing in-process inventory and associated carrying costs. JIT focuses on continuous improvement and can improve a manufacturing organization's return on investment, quality, and efficiency. (Liker, 2004)
Continuous-flow Manufacturing (CFM)	An approach to discrete manufacturing that contrasts with batch production. The goal is an optimally balanced production line with little waste, the lowest possible cost, on-time and defect-free production. (Bowers, 1990)
Takt Time	Derived from the German word Taktzeit, sets the pace for industrial manufacturing lines so that production cycle times can be matched to customer demand rate. (Liker, 2004)
Critical Path Method (CPM)	A method for scheduling a set of project activities. (Kelley,1959)

TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

Page

CHAPTER I

INTRODUCTION

1.1 Background

Since it originated in the Toyota Production System (TPS), many researchers have discussed the application of Value Stream Mapping (VSM) in different industries. Value stream mapping is a lean manufacturing technique used to analyze and design the flow of material and information required to bring a product or service to a consumer (Rother & Shook, 2003). Value stream mapping is a powerful tool that provides a visual view of work processes, improves work strategies and deepens an understanding of eliminating waste and delivering value.

Since 1993, the new philosophy of lean production and the application of value stream mapping have been introduced in construction (Pasqualini & Zawislak 2005). A literature review shows that previous studies on the application of value stream mapping in construction have focused on macro-processes, such as supply chain (Arbulu & Tommelein 2002) or project delivery (Mastroianni & Abdelhamid 2003), or on single operations, such as components manufacturing (Alves et al.2005) and masonry works (Pasqualini & Zawislak, 2005). By definition, value stream mapping analyzes the flow of material and information in a value stream; however, previous studies did not emphasize the flow of information during work processes.

1.2 Objective of the Study

This thesis has two main objectives. The first is an in-depth literature review on value stream mapping, especially concerning useful value stream mapping tools and the application of value stream mapping in construction industry. This portion will form the basis for the author's continued research for new knowledge in this area, but at a PhD level. The other objective is to perform a case study of my own experience in doing this research study and the value stream mapping of my thesis writing process. The purpose of this objective is threefold. The first is to apply the knowledge into practice in order to enhance my learning results and gain a deeper understanding of value stream mapping. By visualizing my thesis writing process, I identified the waste in the process, tried to minimize the waste and made improvement to my work efficiency, which will be applied in my future research studies. The second is that the work flow of my thesis writing can be considered information flow, and applying value stream mapping into the non-visible information flow is a gap found in the literature. Thus, the process can be regarded as an example of applying value stream mapping into information flow. The last goal is that the value stream maps could provide guidance for future construction management graduate students at Texas A&M University.

The results of this thesis include the following: first is the literature summary of value stream mapping, value stream mapping tools and the application of value stream mapping in construction. The second result is the creation of three current state maps of my research study, progress meeting and literature reading processes. By analyzing the

current state maps, the waste was identified and future state maps with improvements to minimize waste were created.

1.3 Significance

First, the literature review of value stream mapping provides an overview of this lean tool, which offers a framework for future study in the application of value stream mapping in construction industry. Second, the case study of my thesis writing process can be regarded as information flow, and applying value stream mapping in the process helps visualize the work and target waste, which enables future improvement toward a better state.

1.4 Limitations

The limitations of my study include the following: first, the literature search is limited to research written in English; valuable studies in other languages could be excluded. Second, in the case study portion, the time for doing one unit of research work (e.g. reading a research paper) varies depending on many reasons. The time recorded will be an average time, and thus may affect the accuracy of the value stream map.

1.5 Delimitation

The scope of the research is delimited to an in-depth literature review of previous studies on value stream mapping and the application of value stream mapping in construction industry. The practice of mapping out my thesis writing process will enhance my understanding of value stream mapping, in preparation for further study in this area in the future.

CHAPTER II

METHODOLOGY

2.1 Introduction

This study focuses on the value stream mapping tool and its application. In order to build the theoretical framework, a comprehensive literature review is important for the first part of this study. The summary of previous research on value stream mapping will provide the larger picture of the current research. . In the second portion of this research, the task is to map the thesis writing process and the method is following the value stream mapping principles identified in the literature review. The value stream mapping method will be discussed in the next chapter.

2.2 Purpose of Literature Review

Literature review is a fundamental part of research. Existing literature provides researchers with background in their interested topics, to know what is going on in their field of study. The process of reading and evaluating articles helps researchers find connections between the existing researches and identify problems or gaps that exist in the published studies. Then researchers start to develop and connect their own ideas to it.

2.3 Types of Literature Review

According to Galvan (2006), there are different types of literature reviews, ranging from selective to comprehensive. A selective review focuses on a small segment of the literature on a topic. A course assignment may be an example of a selective review. In contrast, the literature review in a thesis is a comprehensive review that

provides a holistic view of an interested topic and is part of the graduate thesis. Figure 1 shows the types of literature review.

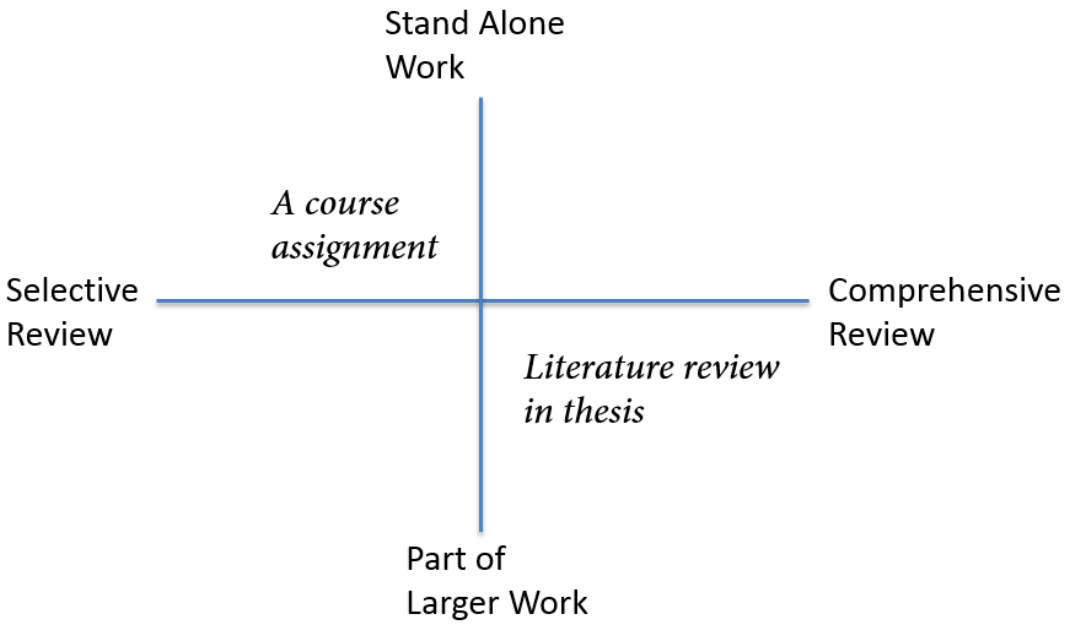

Figure 1. Types of Literature Review (Based on Galvan, 2006)

2.4 Identifying the Literature

The first step in a comprehensive literature review is to be familiar with the databases by identifying the relevant databases in the construction field. The databases used for the literature search include Google Scholar, ASCE Library, Web of Knowledge, GreenFILE, ScienceDirect and ProQuest Dissertations.

After determining the main databases for use, the next step is using keywords to search for literature. A literature review is not a linear process, because as the review of literature proceeds, new keywords might emerge. I started with the general keywords Value Stream Mapping, but the results were too broad for my topic, thus I narrowed down to value stream mapping in construction, value stream mapping tools, etc. After identifying the relevant studies, I exported the references into RefWorks to help me organize the literature. Then, after a further analysis of the literature, I created a literature selection table showing the papers that are related to my research and the reason for choosing them. Table 1 shows the selection of relevant literature papers.

2.5 Analyze and Group the Literature

The next step is to evaluate the relevant literature and select articles, books and other publications that will be useful for the chosen topic. I read the articles and organized them into three different themes: value stream mapping principles, value stream mapping tools and value stream mapping in construction.

2.6 Literature Review Matrix

In reviewing the literature, I created a literature matrix to help overview, organize and summarize the readings. The matrix includes general information, keywords searched, definitions of key terms and concepts, research methods, summary of research results and useful references if applicable. When a relevant reference was identified, it was added to the matrix. Table 2 shows the literature review matrix.

Table 1. Literature Selection Table

	Survey of all literature on the topic VSM			Applicable to research				
item	Journal paper topic	Authors	Year	Yes	No	Maybe	Reason	Notes
1	Learning to see-value stream mapping to create value and eliminate muda	Mike Rother and John Shook	1999	√			An introduction	
2	The seven value stream mapping tool	Peter Hines and Nick Rich	1997	√			good paper introduced seven useful tools in VSM	
3	Learning to see work flow: an application of lean concepts to precast concrete fabrication	Glenn Ballard, Nigel Harper & Todd Zabelle	2003	√			this paper talks about the lead-time reduction for engineeried-to-order product such as precast concrete fabrication.	reducing the lead time forengineered-to-order products can allow more time for exploration and testing of design alternatives, reduction of project durations, or some combination of both.
4	Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study	Fawaz A. Abdulmalek, Jayant Rahgopal	2006			√	about steel manufacturing	
5	Concepts for simulation based value stream mapping	Petter Solding & Per Gullander	2009	√			the paper compared traditionally value stream mapping and discrete event simulation, presents a concept for creating dynamic value stream maps of a system using simulation.	**Simulation** is the imitation of the operation of a real-world process or system over time.[1] The act of simulating something first requires that a model be developed; this model represents the key characteristics or behaviors/functions of the selected physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time.
6	Utilising simulation to enhance value stream mapping: a manufacturing case application	Thomas Mcdonald, Elieen M. Van Aken & Antonio F. Rentes	2010		√		too much about manufacturing	
7	More just-in-time: location of buffers in structural steel supply and construction processes	Iris D. Tommelein & Markus Weissenberger	1999	√			this paper talks about the structural steel frame erection, this production system cannot afford any delays, is managed as a just-in-time process with materials being delivered to site as needed and installed promptly.	the use of symbols from manufacturing is investigated to map key production steps as well as buffers in between them in order to elucidate where resources do and do not flow.
8	A new value stream mapping approach for	M. Braglia, G, Carmignani & F. Zammori	2011	√			VSM use in complex systems. "temporized" bill of material	

Table 2. Literature Review Matrix

No.	TITLE	BIBLIOGRAGH	KEY WORDS SEARCHED	METHODOLOGY	SUMMARY OF RESULT	USEFUL REFERENCE	Key Refernces
1	Competing against ignorance: Advantage through knowledge	Peter Hines, Nick Rich and Malaika Hittmeyer. LeanEnterprise Research Centre, Cardiff Business School, Cardiff, UK	Value Stream Mapping	Case Study	Introduces the Value Stream Analysis Tool(VALSAT) and describes how it can aid in increasing knowledge of the value stream. This article begins by discussing the types of improvements companies want to make, this research included 14 UK large organizations, The results were then tabulated to determine the average importance of each improvement to the group of organizations as a whole. It was noted that the importance ratings would no doubt change over time, and therefore "a dynamic analysis, prioritisation and focusing tool, which if possible should be capable of using both tacit and subjective information as well as explicit or quantifiable information", is needed. The tool described in the paper, VALSAT, meets all the above criteria. The article does a good job of detailing all the steps to follow in using the tool to determine which of the HOWs to undertake so that the most important WHATs are resolved. The article then provides a case study of a Kenyan textile manufacturer to describe the practicality of the tool. The article concludes by listing some of the advantages and disadvantages of the VALSAT.	Ahlswede, R., Cai, N., Li, S. Y., & Yeung, R. W. (2000). Network information flow. Information Theory, IEEE Transactions on, 46(4), 1204-1216. Howell, G., & Ballard, G. (1998). Implementing lean construction: understanding and action. 6th Annual Conference of the International Group for Lean Construction.	Howell, G., & Ballard, G. (1998). Implementing lean construction: understanding and action. *6th Annual Conference of the International Group for Lean Construction* .
2	Seven value stream mapping tools	Peter Hines and Nick Rich	Value Stream Mapping	Grounded Theory	This article describes a toolkit consisting of seven tools that, when used together, provides an effective framework for identifying and eliminating wastes. The article begins by stating that the difference between a supply chain and a value stream is that a supply chain encompasses all of the activities of all the companies involved, whereas a value stream only refers to the specific activities which actually add value to the product or service. Next, the three types of activities (non-value adding NVA; necessary but non-value adding NNVA and value-adding VA), with examples, are presented, followed by an excellent description of each of the seven basic wastes. 1. overproduction 2. waiting 3. transport 4.inappropriate processing 5. unnecessary inventory 6. unnecessary motion and 7. defects. The article discusses problems with existing tools for analyzing value streams. The main problem identified was that each of these tools was too limited in scope and did not integrate well with one another in order to provide a comprehensive view of the value stream. The seven tools presented in the article were specifically designed to eliminate this problem. The first tool, process activity mapping, aids in developing solutions to reduce waste. The second tool, supply chain response matrix, aids in identifying the activities constraining the process so that these activities can be targeted for improvement. The third tool, production variety funnel, is similar to IVAT analysis and helps one understand how products are produced. The fourth tool, quality filter mapping, aids in identifying where quality problems occur. The fifth tool, demand amplification	Womack, J. and Jones, D., "From lean production to the lean enterprise", Harvard BusinessReview, March-April 1994, pp. 93-103. Shingo, S., A Study of the Toyota Production System from an Industrial Engineering Viewpoint, Productivity Press, Cambridge, MA, 1989.	Womack, J. and Jones, D., "From lean production to the lean enterprise", Harvard BusinessReview, March-April 1994, pp. 93-103.
3	A theory of waste and value	Jose L. Fernandez-Solis and Zofia K. Rybkowski	Waste in Constructino	Grounded Theory	Waste and value are ambiguous concepts, making it difficult to visualize where and how they occur in construction. This paper visualizes waste and value in construction at three scales: systemic, (waste resulting from a major contract break down) synergistic (the sum of waste is greater than its parts) and discrete (quantifiable) and from the perspectives of stakeholders: owners (strategic), planners (logistics) and workers (tactical). Wastes include: time waste, material, primitive technology waste, labor waste, energy/resource waste, financial waste, unrealized potential waste and defect, process waste and risk waste. And in value and waste analysis, typically consider the following factors: productivity, cost and schedule growth, profitability, predictability, variability, relationships, innovation, wages, health and safety, business ethics, environmental performance and whole service life. Then the paper talked about the three scales of waste, the relationship of waste and value. Formoso define construction waste as "any losses produced by an activity that generate direct or indirect costs but do not add any value to the product from any point of view to the client." This paper argues that discrete, synergistic and systemic wastes exist in the same ambit where the values exist, where waste is the inverse opposite of value. Then elaborated the waste schema involved in each level and the relations with stakeholders. Then the authors talked about the 2 choices of elimination of waste, either an increased percentage of value per same project cost, or reduced project cost for delivery of the same amount of value. This paper gave a macroscopical view of the value and waste in the construction industry, which is very informative and help me build a fundamental knowledge of the waste in the construction setting.	Lee, Sunku (2001). New method for classifying construction information. Master's thesis, Texas A&M University.	Lee, Sunku (2001). New method for classifying construction information. Master's thesis, Texas A&M University.
4	Value stream management	Peter Hines, Nick Rich, Jogn Bicheno, David Brunt and David Taylor	Value Stream Mapping	Descriptive	This paper describes the method in detail including a summary of the previous Value Stream Mapping approach and its weaknesses. Value Stream Management is a new strategic and operational approach to the data capture, analysis, planning and implementation of effective change within the core cross-functional or cross-company processes required to achieve a truly lean enterprise. The paper started with talking about a number of problems, constraints and issues have arisen when using the Value Stream Mapping approach during the Lean Processing (LEAP) Program, a three year government and industry funded research program in the UK. Those problems can be divided into 3 areas 12 sub-questions that mentioned in the paper. Then the new methodology of value stream management was introduced, it is a strategic and operational approach designed to help a company or complete supply chain achieve a lean status. The new approach can be divided into 20 individual and consecutive stages and illustrated in the paper, and then detailed explanation was made to each stage. The authors introduced many other aspects associated with this new approach and during the process; the LEAP team was able to identify 12 wastes (including the original seven wastes) and introduced 3 new tools in addition to the 7 tools that introduced before. This article gives a new perspective in value stream mapping, the extensive analysis and explanation of wastes and ways to remove them provided many new ideas that need to be considered.	Yu, H., Tweed, T., Al-Hussein, M., & Nasseri, R. (2009). Development of lean model for house construction using value stream mapping. *Journal of Construction Engineering and Management* , *135* (8), 782-790.	
5	Development of Lean Model for House Construction Using Value Stream Mapping	Haitao Yu; Tarry Tweed; Mohamed AL-Hussein and Reza Nasseri	Value Stream Mapping Construction	Case Study	Lean construction has recently attracted considerable attention in the home building industry. Lengthy delivery time and significant waste in the construction process have caused many home builders to seek a more effective production model that will increase process reliability, reduce total lead time, and improve quality. However, although housing construction provides the closest analogy to manufacturing, a high level of variability prevents the direct transplantation of lean paradigm and techniques. In collaboration with a local homebuilder, this research developed a systematic approach based on value stream mapping techniques to analyze the current process and to formulate a lean production model. The model has four main features: synchronized first-in, first-out lane-based flow, production leveling at pacemaker, work restructuring, and improved operation reliability. This paper made a good explanation of how value stream mapping works in the construction industry and pointed out a number of factors impeditailed explanation was made to each stage. The authors introduced many other aspects associated with this new approach and during the process; the LEAP team was able to identify 12 wastes (including the original seven wastes) and introduced 3 new tools in addition to the 7 tools that introduced before. This article gives a new perspective in value stream mapping, the extensive analysis and explanation of wastes and ways to remove them provided many new ideas that need to be considered. her an increased percentage of value per same project cost, or reduced project cost for delivery of the same amount of value. This paper gave a macroscopical view of the value and waste in the construction industry, which is very informative and help me build a fundamental knowledge of the waste in the construction setting.in the supply chain where actual demand pull gives way to forecast-driven push". The seventh tool, physical structure, aids in developing a high-level understanding of the supply chain. The selection of "which tools to use in what circumstances is done using a simplified version of the value stream	Alves, T.C.L., tommelein. I.D., and Ballard, G (2005). "Value stream mapping for make-to-order products in a job shop environment." *Proc., research congress 2005*, ASCE, Reson, VA Ballard, G. (2001). "Cycle time reduction in home building." *Proc., 9th annual Conf., Int. Group for Lean Construction*, National Univ. of Singapore, Singapore Ballard, G., Harper, N., and Zabelle, T. (2003). "Leaning to see work flow: an application of lean concepts to precast concrete fabrication." *Eng., Constr., Archit. Manage.* , 10(1),6-14 Pasqualini, F., and Zavislak, P. A. (2005). "Value stream mapping in construction: a case study in a brazilian construction company." *Proc., 13th Annual Conf., Int. Group for Lean construction*, Univ. of New South Wales, Sydney, Australia.	Value stream mapping in construction: a case study in a brazilian construction company. Proc., 13th Annual Conf., Int. Group for Lean constrcution, Univ. of New South Wales, Sydney, Australia.
6	Concrete slab value stream mapping of Brazillian residential buildings- a lean construction study case	Patricia Stella Pucharelli Fontanini, Caroline de Souza Milano, Aparecido Fujimoto, etc.	Value Stream Mapping Construction	Descriptive Case Study	This paper introduced a case study of the concrete slab produce process of the Brallian Company. This paper presented the application of VSM and the preliminary sustainable analyses too. The execution of research started with the diagnosis of lean and sustainable concepts selected, and an analysis initial of the value stream mapping applicability in the concrete slab processes. In the first step, three visits were carried out at the residential works, aiming to detect and to observe the waste inherent in construction processes. In a second step, the authors analyzed the company. In the third step, the search consisted in the implementation of semi-structured interviews with the engineer responsible for the work and other work employees. In the sequence, it was chosen a standardized process for value stream mapping of current state (concrete slab process). As a result, through the analysis of the mapping performed, it was possible to identify waste that could be prevented and then it was proposed a future state for the flow that resulted in a better performance of the process making it more lean and sustainable. This paper gave a case example of how VSM contributes to making decisions about the flow represented making it logical and simplified, the production process, addressing lean techniques	J.P. Womack: *the challenge of vlaue stream management*. Lean Enterprise institute value stream management conference. Dearborn, 2000 M.Rother: *Crosscoads: which way will you turn on the road to lean?* In: LIKER, J.K. (Editor): Becoming lean: inside stories of U.S. MAnufactures. portland, Oregon, USA: Productivity press,1997	J.P. Womack: the challenge of vlaue stream management. Lean Enterprise institute value stream management conference.

2.7 Synthesize the Literature

In writing a literature review, the goal is to synthesize the literature into an integrated review. As previously noted, there were three major themes: value stream mapping principles, value stream mapping tools and the application of value stream mapping in construction. In writing the literature review, not only should the literature be summarized under the three themes, but one should also try to identify and understand the connections among the studies.

2.8 Summary

The literature review is a vital process that sets the background of this research. By reviewing the published literature, I understood the current research on value stream mapping, the different value stream mapping tools and how to use value stream mapping to visualize work and make improvements. The process includes exploring the topic, collecting literature, reading articles, taking notes, shaping ideas, keeping track of citations and writing the literature review. However, as mentioned before, the steps are not linear, one step does lead to the other, but once I identified useful references, I would go back to an earlier steps as I knew more about the literature and topic. Figure 2 shows a literature review process based on the guidelines of doing a literature review according to Galvan and my understanding.

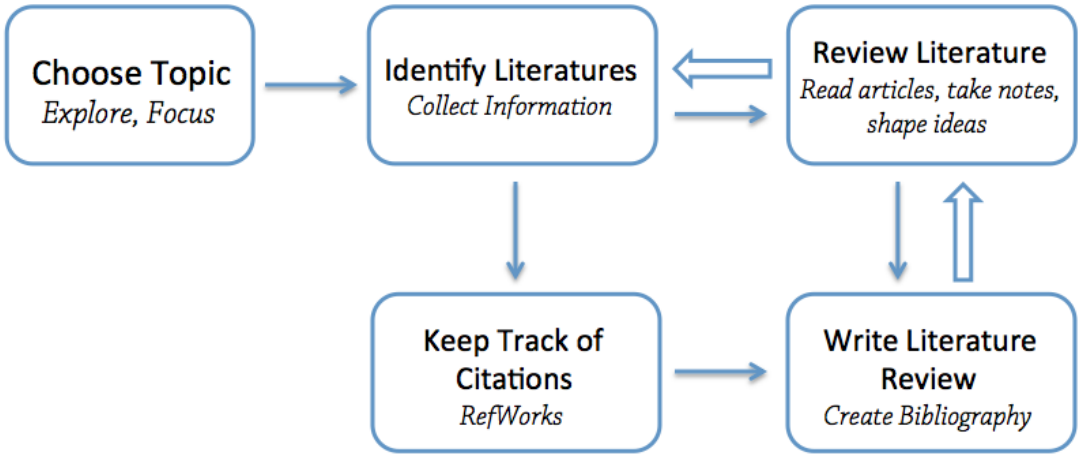

Figure 2. Literature Review Process (Based on Galvan, 2006)

CHAPTER III

LITERATURE REVIEW

The following sections summarize the literature review from several main aspects according to keywords.

3.1 Value Stream Mapping

3.1.1 Value Stream

The term value stream was first used in the book *The Machine that Changed the World* (1990) by Womack, Jones and Roos, and further discussed in *Lean Thinking* (1996) by Womack and Jones. In a later book by Martin and Osterling, the authors defined: "a value stream is the sequence of activities an organization undertakes to deliver on a customer request." (Martin and Osterling, 2013). More broadly, "a value stream is the sequence of activities required to design, produce, and deliver a good or service to a customer, and it includes the dual flows of information and material." (Martin and Osterling, 2013). The activities in a value stream can be the work performed by the organization itself, as well as the work performed by outside parties; even the customers can be a part of a value stream. There are different types of value stream. The main type is one that a good or service is requested by and finally delivered to an end customer. A value-enabling or support value stream is a value stream that supports the delivery of value (e.g. IT support, hiring, product design).

3.1.2 Value Stream Mapping

Value stream mapping in the manufacturing environment has been discussed since the technique was used at the Toyota Motor Corporation, and was known as

"material and information flows." Toyota focuses on understanding the flow of material and information across the organization as a way to improve manufacturing performance. Pictorial representations with process maps are ways to communicate with different parties in an organization. In this way, value stream maps can provide a whole view of how work are done through the entire systems.

In the book *Value Stream Mapping: How to Visualize Work Flow and Align People for Organizational Transformation* (2013), Martin and Osterling summarized the benefits of value stream mapping as the following.

(1) The visual unification tool can help in visualizing non-visible work, such as information exchanges. Visualizing non-visible work is a key step in understanding how work gets done.

(2) Value stream maps can create connections to the customer, which helps an organization focus more on the customer's perspective and deliver more value to the customer.

(3) Value stream maps can provide a holistic system view by connecting disparate parts into a more collaborative organization, with the objective of providing higher value to customers.

(4) Value stream mapping can help in visualizing and simplifying the work process at a macro level, which may help in making strategic improvement decisions better and faster.

(5) Value stream maps are effective means to orient newcomers by helping them understand a holistic view and where they fit in an organization.

To sum up, value stream maps provide a visual, full-cycle macro view of how work progresses from a customer request to the final fulfilment of that request. The mapping process deepens the understanding of work systems that deliver value to customers and reflect the work flow from a customer's perspective. As a result, the process of value stream mapping provides effective ways to establish strategic directions for better decision making and work design.

3.1.3 Create a Value Stream Map

Drawing a value stream map is the result of implementing a VSM tool. In the pioneering work of Rother and Shook (2003), the landmark book *Learning to See* provided the first way to "see" the value streams that Womack et al. introduced. According to Rother and Shook, the process of creating a value stream map can be briefly summarized as:

(1) Identify the target product, process family or service.

The process family is a group of products or services that go through the similar or same processing steps or the most problematic process family that needs to be improved.

(2) Draw the current state value stream map.

The current state map should illustrate how the exact activities are performed in a real working context. To create a current state map, collect data and information by walking the flow and interviewing the people who perform the tasks. With the information gathered through the process, the current state value stream map can be created using pre-defined symbols representing different elements in the value stream,

which shows the information, process steps required and current delays to deliver the request product or service to the customer.

(3) Analyze the current state value stream map.

After the current state map is completed, the team may go through the process of assessing the current state value map in terms of creating flow by eliminating waste. In this step, there are several lean principles that can facilitate the improvement of the value stream (e.g., takt time, continuous flow, etc.).

(4) Draw a future state value stream map

The purpose of value stream mapping is to highlight sources of waste and eliminate them within a short period of time. The future state map should be based on an assessment of the current state map and make improvements that can be achieved. Through implementing a future-state value stream, the goal can become a reality.

(5) Work toward the future state condition

A plan for achieving the future state is crucial; otherwise, value stream maps are pointless. The plan for achieving the future state value stream can be a future state map, detailed process map, a yearly value stream plan or a combination of those documents.

3.2 Value Stream Mapping Tools

Before learning the tools used in VSM to eliminate waste, an understanding of the types of waste that might occur is necessary. In manufacturing, there are three types of operations that are undertaken (Monden, 2011): (1) Non-value adding; (2) Necessary but non-value adding; and (3) Value-adding. The first is pure waste with unnecessary actions that should be completely eliminated. The second one involves actions that are

necessary but might be wasteful. Value adding operations are the process that converting raw materials into finished products through the use of manual labor. According to Jones (1995), there are seven wastes in the Toyota production system. They are: faster-than-necessary pace, waiting, conveyance, processing, excess stock, unnecessary motion and correction of mistakes.

In the study conducted by Hines and Rich (1997), seven new tools are presented regarding the seven wastes. The first tool, process activity mapping, helps in generating solutions to reduce waste. Table 3 is the map drawn according to Hines and Rich. First, analyze and study the flow of processes, then record in detail all items required in each process. Next, list each process and categorize into activity types (e.g., operation, transport, inspection and storage); darker shade box shows the type. Then, identify any waste in the processes and consider a better and more efficient way to rearrange the process.

Table 3. Process Activity Mapping, Hines and Rich (1997)

#	STEP	FLOW	MACHINE	DIST(M)	TIME(MIN)	PEOPLE	OPERATION	TRANSPORT	INSPECT	STORE	DELAY	COMMENTS
1	RAW MATERIAL	S	RESERVOIR				O	T	I	S	D	ADDITIVES
2	KITTING	O	WAREHOUSE	10	5	1	O	T	I	S	D	
3	DELIVERY TO LIFT	T		120			O	T	I	S	D	
4	OFFLOAD FROM LIFT	T			0.5	1/2	O	T	I	S	D	
5	WAIT FOR MIX	D	MIX AREA		20		O	T	I	S	D	
6	PUT IN CRADLE	T		20	2	1/2	O	T	I	S	D	
7	PIERCE/POUR	O	MIX AREA 12		0.5	1	O	T	I	S	D	
8	MIX(BLOWERS)	O			20	1/2	O	T	I	S	D	BASE MATERIAL BLOW& ADDITIVES
9	TEXST #1	I			30	1+1	O	T	I	S	D	SAMPLE/TEST
10	PUMP TO STORAGE TANK	T	STORE TANK	100		1	O	T	I	S	D	DEDICATED RESERVOIR
11	MIX IN STORAGE TANK	O	STORE TANK		10	1	O	T	I	S	D	
12	J.R. REST	I			10	1+1	O	T	I	S	D	STAMP& APPROVE

The second tool, supply chain response matrix, helps identify the critical lead-time activities constraining the process, in order to target these activities for improvement. Figure 3 shows an example supply chain response matrix. The horizontal axis indicates the lead time for the product. In this example, the cumulative lead time is 42 days. The vertical axis shows the cumulative inventory in the supply chain, which represents an additional 99 working days, thus the total lead time is 141 days. Each of the activity lead times can be targeted for improvement.

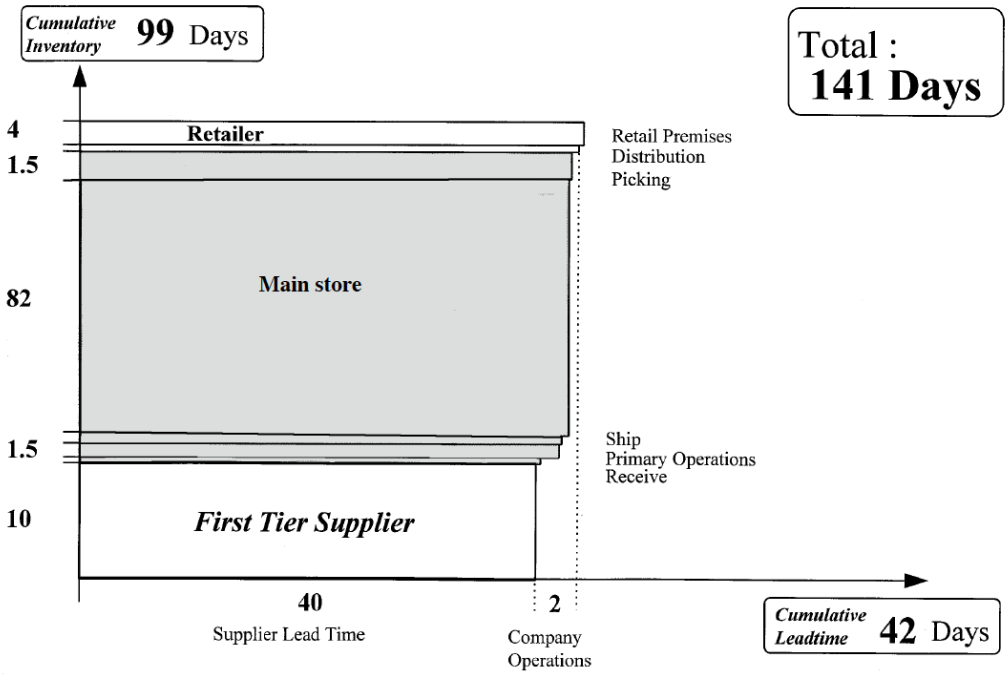

Figure 3. Supply Chain Response Matrix, Hines and Rich (1997)

The third tool, production variety funnel, aids in understanding how products are produced and how a company or supply chain operates. This tool helps the mapper to target inventory reduction and gain an overview of the company. Figure 4 shows the production variety funnel of a brewing industry case.

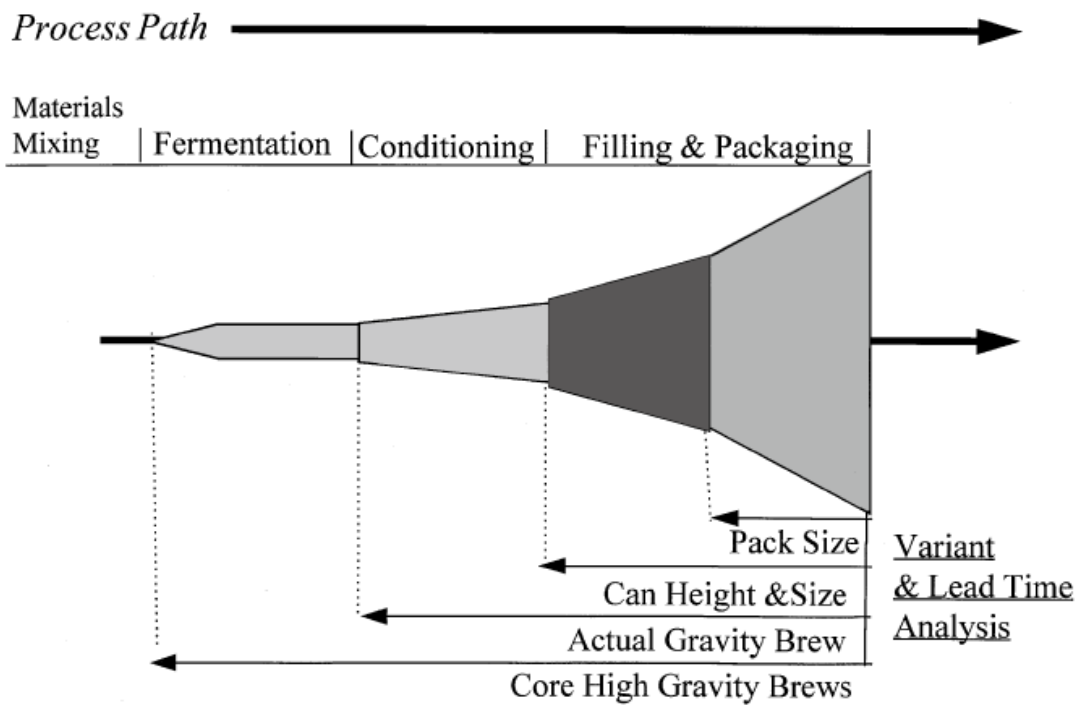

Figure 4. Production Variety Funnel, Hines and Rich (1997)

The fourth tool, quality filter mapping, helps to identify where quality problems occur. There are three types of defects: the first is product defect, which is when defects are not caught by inspections and are passed to customers. The second is quality defect, or service defect, e.g. inappropriate delivery (early or delay), or any defect associated with customers' experience. The third defect is internal scrap, which refers to product defects that have been caught by inspection checks. Then the three defects are mapped out; Figure 5 is an example of a quality filter map.

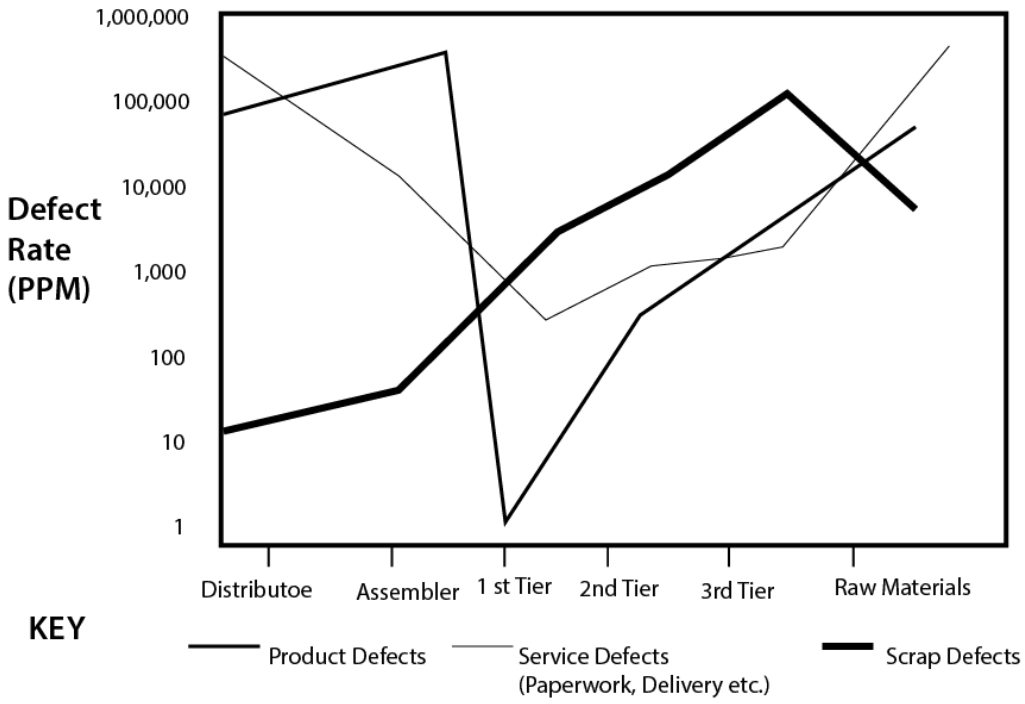

Figure 5. Quality Filter Mapping, Hines and Rich (1997)

Using the mapping process, it is easier to identify where defects are occurring and to make improvement to minimize waste.

The fifth tool, demand amplification mapping, helps in analyzing demand variability. A demand amplification map shows how demand changes along a supply chain, and analysis and decisions can be made using the information. Figure 6 is a demand amplification map of one food company. Two curves are plotted: the lighter shaded one is actual customer sales while the darker curve represents orders placed with the supplier to fulfill this order. From the map, the variability of supplier orders is much higher than the consumer sales. Analyzing the demand changes along the supply chain helps in managing the fluctuations or redesigning the value stream.

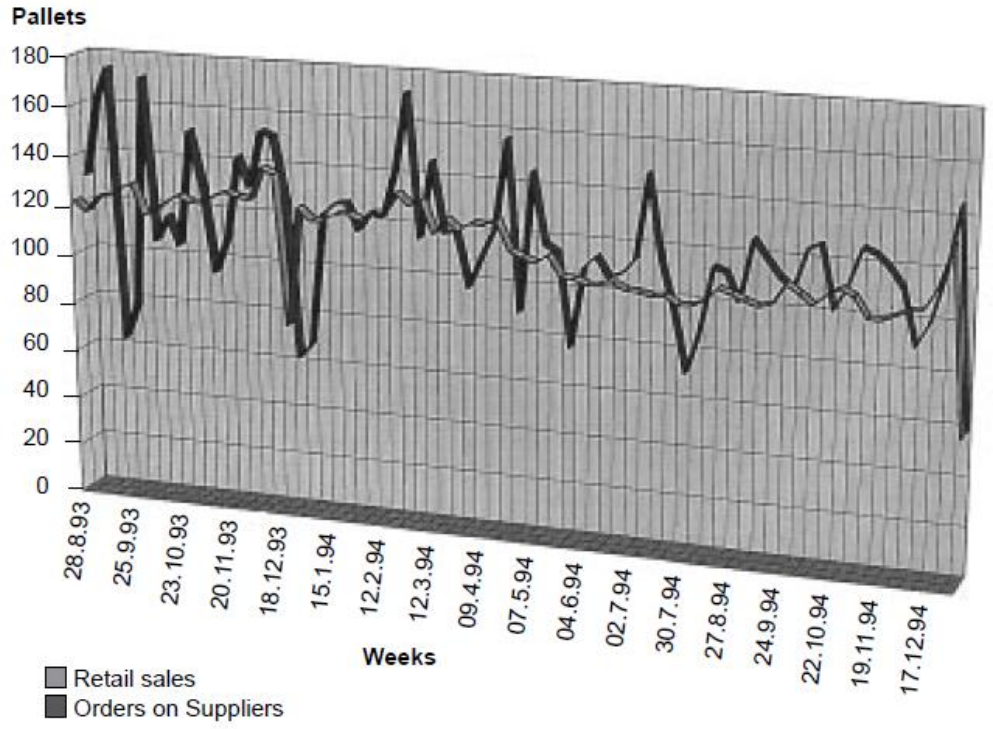

Figure 6. Demand Amplification Mapping, Hines and Rich (1997)

The sixth tool, decision point analysis, aids in identifying "the point in the supply chain where actual demand-pull gives way to forecast-driven push" (Hines and Rich, 1997). In other words, it is the point where products stop being made according to actual demand and are made against forecast only. This tool shows where that point exists. Figure 7 is an example from a food company that shows the decision point analysis. Knowing where the point is enables the planner to assess the processes operating upstream and downstream from this point. The purpose is to make sure they are working under the same pull or push philosophy. From a long-term perspective, it provides various scenarios to see what the result is if the point is moved.

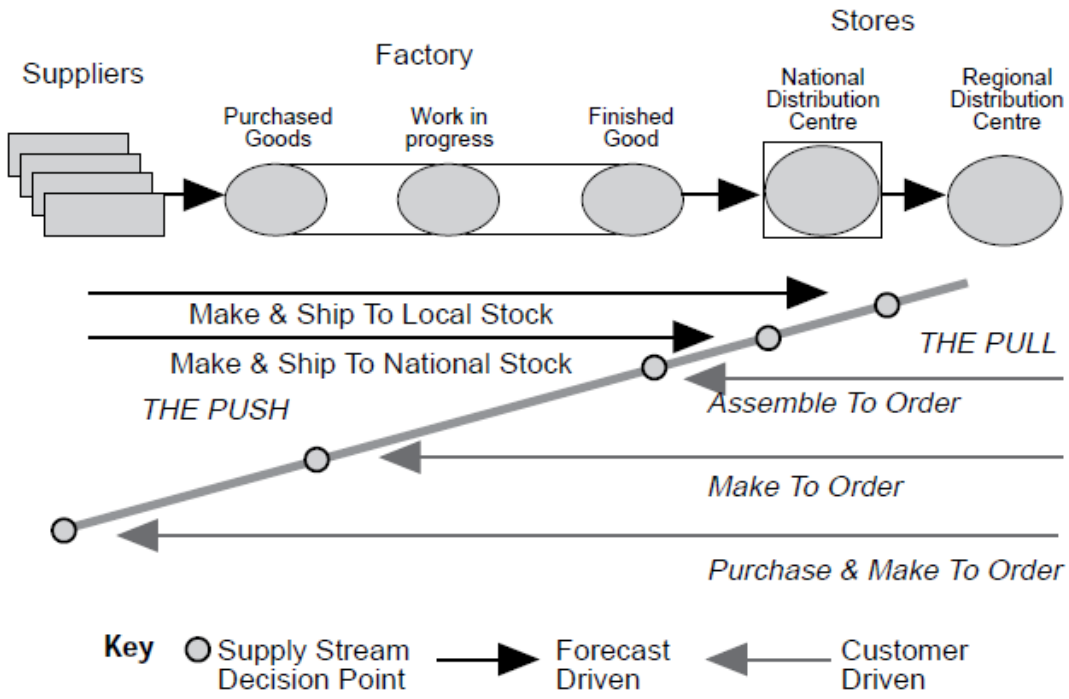

Figure 7. Decision Point Analysis, Hines and Rich (1997)

The seventh tool, physical structure, provides an overview of the supply chain at an industry level. It helps with understanding how an industry operates and brings attention to areas that might need improvement. Figure 8 illustrates the physical structure mapping tool that can be split into volume structure and cost structure. The volume structure has various tiers in both distribution and supplier areas, and the assembler is in the middle. The structure shows the organizations involved in the value stream. In each part, the areas are proportional to how many organizations are there. The cost structure is similar to the volume structure; however, the areas are linked to the cost-adding process. In this example, the most cost adding in raw material acquiring is the first tier. The purpose of the cost volume is to analyze the value adding required in the final product when selling to the consumer.

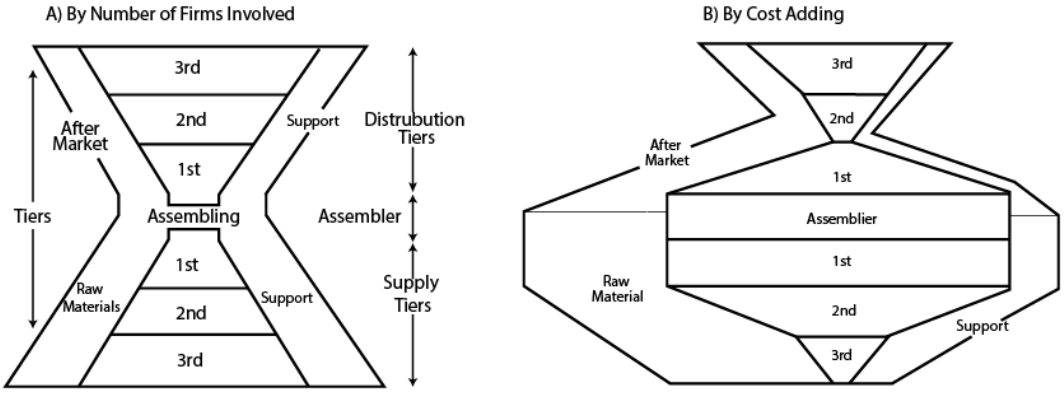

Figure 8. Physical Structure, Hines and Rich (1997)

In a later study, the Value Stream Analysis Tool (VALSAT) is introduced. (Hine et al. 1998). This tool provides an organization with a deeper understanding of its value stream, which the WHATs represent the required improvements according to customer needs, and the HOWs represent the possible techniques in achieving these improvements. VALSAT helps determine which of the HOWs to implement so that the most important WHATs can be resolved.

The tools introduced above can be applied in combination or singularly, based on the requirements of the individual value stream (Hines & Rich 1997). Thus, choosing among the tools to effectively eliminate the waste in any value stream becomes vital.

3.3 Value Stream Mapping in Construction

"Since 1993, the ideas of Lean Production have been introduced in construction, creating Lean Construction" (Pasqualini & Zawislak 2005). The application of the value stream mapping tool, which represents the main principles of Lean Production, also have been introduced to the construction industry. In spite of being successfully applied into different industries, the application of value stream mapping in construction still has not been fully disseminated. There are few studies about VSM in construction, and they refer more to construction supplies than to the productive process itself (Fontanini & Picchi 2004).

According to Yu et al. (2009), a number of inhibiting factors for applying value stream mapping to the construction industry include:

(1) An underlying prerequisite for VSM is the repetition of the production process.

(2) VSM is a quantitative tool that uses a list of process data to depict the current state of the process and to determine what the future state will be. However most of construction companies usually do not fully track the construction processes and data.

(3) Key concepts/elements used in VSM, such as inventory, cycle time, takt time and change-over time are defined in the manufacturing context and seem not applicable to construction.

Modifications of VSM were necessary due to the differences between manufacturing and construction (Pasqualini & Zawislak 2005). Two examples in previous studies show how VSM can be modified for the application in construction.

The first one is a case study introduced by Pasqualini & Zawislak in 2005. The study described the modified application of VSM in a Brazilian construction company; some adaptations were made in each stage of VSM.

First, each stage in construction occurs over a long period of time and the different processes produce different products. Instead of selecting a family of products to initiate VSM in construction, this study selected a stage of the productive process of construction, which in this case was the masonry stage.

For the current state map, since the time of production in construction is too long to collect in s single day, the way to solve the problem is to obtain the average time of a stage. In the analysis of the current state map, based on the schedule developed from the contract, the takt time can be calculated, which is the effectively available worked time multiplied by the amount of square meters to be worked on for the same stage. As a result, takt of the construction will indicate the time in which a square meter should be

worked, or the rhythm of production according to the contract states the customer's demand. The concept of this modification is to divide one construction state into units so that the work to be done per unit can be regarded as repetitive and the flow becomes continuous. Based on the analysis of the current state map, a future state map can be drawn in the same way that occurs in manufacturing context.

Another example is a case study of housing construction. Yu et al. (2009) worked on a case study of the standard wood platform-frame structure, the case of 400 houses construction were regarded as repetitive works.

Ballard (2001) suggested that variability was the major source of waste in construction and that even-flow production could increase the reliability of work flow and thus reduce the cycle time. Bashford et al. (2003) further discussed the implications of even flow in construction and suggested that the idea had a minor impact on construction activities duration, but could reduce the workflow variability. This study by Yu et al. continues Ballad and Bashford's efforts on house production flow by applying value stream mapping to achieve even flow.

The products of a home building can be seen as a single product family, because they are constructed following similar processing steps and sharing the same sub-contractors. However, the level of mapping should be determined since the building construction process is a complex system that consists of hundreds of activities and involves a lot of trade contractors. In construction, the houses do not move along a production line but, rather, workers move from one house to another. Thus the operations done by a trade crew can be regarded as a continuous flow. In this case, one

house production process was divided into five stages after considering the size of the value stream map, logical relationship and the total duration of the construction activities. The five stages are foundation, lock-up, interior and siding, pre-finals and finals. After identifying the target stage to be improved, which is the foundation stage in this case, a current state map can be drawn.

The future state map can be developed after the analysis of the current state map, during which waste is identified. The focus of the future state map is to eliminate the cause of waste and improve the value stream into a smooth flow. Four measures were taken in the future state mapping. They are establishing a production flow and synchronizing it to takt time; leveling production at the pacemaker task; restructuring work and improving operational reliability with work standardization; and total quality management for this study.

3.4 Summary

The literature review provides a current study of value stream mapping, specifically its principles and tools, and the current application in construction. Future research could be conducted for the further application of the different value stream mapping tools in the construction industry.

CHAPTER IV

CONCLUSIONS

This research provides an overview of value stream mapping, different value stream mapping tools, and the application of value stream mapping in construction industry. The literature review provides the basis for future study of applying value stream mapping tools in the construction industry. The value stream mapping case study of the research study process puts the learning into practice. Through this application, I have recognized the advantage of value stream mapping over other tools and gained a deeper understanding of the powerful lean tool. Visualizing the non-visible information flow helps in targeting the waste embedded in my working process that needs to be improved. As a result, the improved value stream maps can be guidelines for my future studies. The value stream mapping of a research study is a mapping of information flow in the work process, however it is limited to a simple and micro level. Further research is needed to explore the application of value stream mapping in construction information flow at a more complicated and macro level.

REFERENCES

Alves, T., Tommelein, I. D., & Ballard, G. (2005). Value stream mapping for make-to-order products in a job shop environment. *Construction Research Congress.*

Arbulu, R. J., & Tommelein, I. D. (2002). Value stream analysis of construction supply chains: case study on pipe supports used in power plants. In Proc. Tenth Annual Conference of the International Group for Lean Construction (pp. 183-195).

Ballard, G. (2001, August). Cycle time reduction in home building. In-*Proceedings of the 9th Annual Conference of the International Group for lean construction*.

Bashford, H. H., Sawhney, A., Walsh, K. D., & Kot, K. (2003). Implications of even flow production methodology for US housing industry. *Journal of Construction Engineering and Management*, *129*(3), 330-337.

Bowers Jr, G. H. (1990). Continuous flow manufacturing. *Semiconductor Manufacturing Science Symposium*, 1990. ISMSS 1990. IEEE/SEMI International (pp. 5-8). IEEE.

Fontanini, P. S., & Picchi, F. A. (2004). Value stream macro mapping–a case study of aluminum windows for construction supply chain. In *Twelfth Conference of the International Group for Lean Construction (IGLC 12)* 576-587.

Galvan, J. L. (2006). *A Guide for Students of the Social and Behavioral Sciences*. Pyrczak Publishing.

Hines, P., & Rich, N. (1997). The seven value stream mapping tools. *International Journal of Operations & Production Management*, *17*(1), 46-64.

Jones, D. (1995). Applying Toyota principles to distribution. *Supply Chain Development Program I.*

Kelley Jr, J. E., & Walker, M. R. (1959). Critical-path planning and scheduling. E*astern joint IRE-AIEE-ACM computer conference (pp. 160-173).* ACM.

Liker, J. K. (2004). *The Toyota way: 14 Management principles from the world's greatest manufacturer.* New York: McGraw-Hill.

Martin, K., & Osterling, M. (2013). *Value stream mapping: how to visualize work and align leadership for organizational transformation*. New York: McGraw-Hill.

Mastroianni, R., & Abdelhamid, T. (2003). The challenge: The impetus for change to lean project delivery. In Proc., IGLC-11, 11th Conf. of Int. Group for Lean Construction (pp. 418-426).

Monden, Y. (2011). *Toyota production system: an integrated approach to just-in-time.* Boca Raton: CRC Press.

Pasqualini, F., and Zawislak, P.A. (2005). Value stream mapping in construction: A case study in a Brazilian construction company." Proc., 13th Annual Conference International Group for Lean Constrcution, University of New South Wales, Sydney, Australia.

Rother, M., & Shook, J. (2003). *Learning to See: Value-Stream Mapping to Create Value and Eliminate Muda: Version 1.3 June 2003*. Lean Enterprise Institute.

Womack, J. P., & Jones, D. T. (1996). *Lean thinking: banish waste and create wealth in your corporation.* Simon and Schuster.

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The machine that changed the world: The story of lean production--Toyota's secret weapon in the global car wars that is now revolutionizing world industry.* Simon and Schuster.

Yu, H., Tweed, T., Al-Hussein, M., & Nasseri, R. (2009). Development of lean model for house construction using value stream mapping. *Journal of Construction Engineering and Management*, *135*(8), 782-790.

APPENDIX

A CASE STUDY OF MY RESEARCH STUDY PROCESS

5.1 Introduction

The case study of my research mapping process visualizes my workflow during the whole study. Through this practice, I have deepened my understanding of value stream mapping and enhanced my ability to apply what I have learned from the literature review. Also, by analyzing the current state map of my thesis writing, I can identify the waste that exists and try to improve the value stream by minimizing or even eliminating the waste. The value stream mapping is also one process in the research. My value stream mapping process will follow the principles from the book: Value Stream Mapping: How to Visualize Work and Align Leadership for Organizational Transformation (2013), by Marting and Osterling.

5.2 The benefits of value stream mapping

From the literature review and my gradual learning about lean principles, I realize that value stream mapping is a powerful lean tool that can provide an overall view of how work flows. Visualizing non-visible work is the first step in knowing how work gets done, thus the work can be further analyzed to see where waste exists. The benefit of value stream mapping is summarized as follows:

(1) Value stream mapping helps in identifying waste.

(2) By providing a full-cycle view, value stream mapping deepens the understanding of processes required in delivering value.

(3) Value stream mapping shows the information flow through the processes.

(4) Value stream maps offer a direction for improvement.

(5) The quantitative nature of value stream mapping makes improvement quantifiable.

Since this is my first time doing a research study, mapping the research process may provide an overview of how my work flows so that I can evaluate my progress as well as discover problems and make continuous improvement. I regard this is a meaningful task not only for the research study, but also as a beneficial skill for future research studies. It will have a long-lasting transformational effect.

5.3 Planning the value stream mapping

The Plan-Do-Study-Adjust (PDSA) cycle is one of several scientific methods for problem solving, making improvements and designing work of all types (Martin & Osterling, 2013). Many companies, such as Toyota Motor Corporation, adopted the idea of PDSA as management principles. It is also an important method for achieving continuous improvement. Value stream mapping is an important part of the PDSA cycle. Figure 9 shows a PDSA cycle.

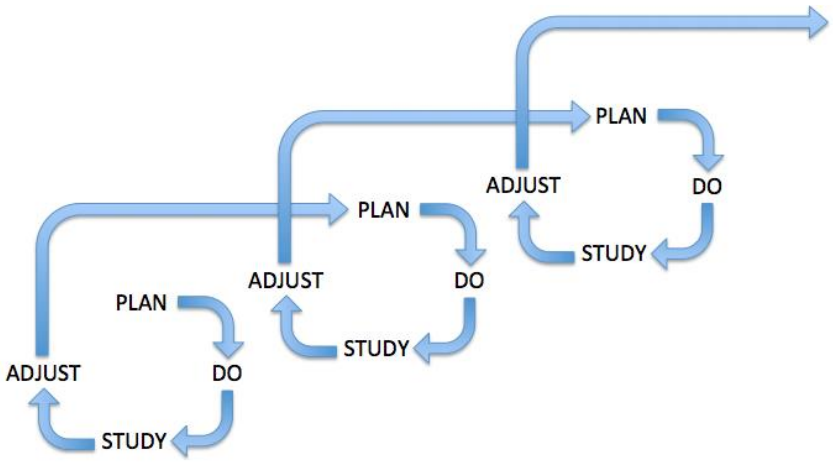

Figure 9. Cycle of Continuous Improvement, Martin and Osterling(2013)

Thus, my first step is to plan the scope and prepare to structure the mapping activities. Appropriate planning is essential when determining the scope of a project, and deciding what is included in the value stream. This warrants focusing on the processes that might be problematic in order to devise successful solutions for any problems. Figure 10 shows my value stream mapping phases and timing.

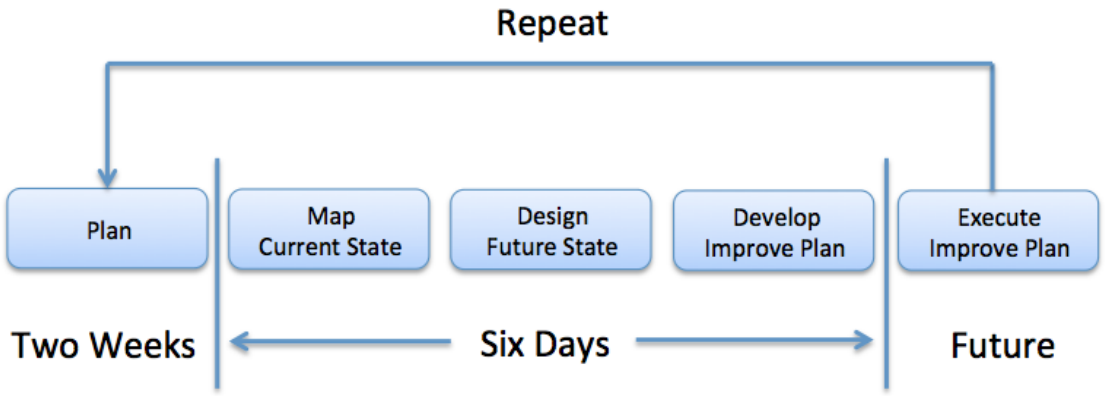

Figure 10. Value Stream Mapping Phases and Timing

5.3.1 Developing a value stream mapping charter

According to Martin and Osterling, a value stream mapping charter reflects the scope, conditions, and resources of a value stream map, which may affect its success. The purpose of the charter is fourfold: planning, communicating, aligning, and building consensus. Although my research study of value stream mapping might not have all aspects in the charter, as practice, I am including this part in my process. Table 4 is an example charter Martin and Osterling suggest.

Table 4. Value Stream Mapping Charter, Martin and Osterling (2013)*

Value Stream Mapping Charter

Scope		Accountable Parties		Logistics	
Value Stream	Value stream being improved	Executive Sponsor	Required: typically VP or C-level	Event Dates & Times	3 days typically; consecutive is best; 6 hrs per day minimum; 7 or 8 hrs is best
Specific Conditions	What circumstances are included and excluded? (e.g., type of customer, geographic location, etc.)	Value Stream Champion	If needed—often director or manager level		
Demand Rate	How many times is this done per wk, qtr, mo, or yr?	Facilitator	Required: skilled, objective person leading the activity	Base-camp Location	On-site, ample wall space, quiet/private location
Trigger	What initiates the process?				
First Step	Task on first process block	Logistics Coordinator	Not always needed	Meals Provided	Always a nice touch; keeps the team from wandering
Last Step	Task on last process block				
Boundaries & Limitations	What is the team NOT authorized to change?	Briefing Attendees ** required *optional	List the the people that are required to attend the briefings (**) and those whose attendance is optional (*).	Briefing Dates & Times	Aids in consensus building and organizational learning. Typically the last hour of the day.
Improvement Time Frame	Typically 3-6 months				

Current State Problems & Business Needs	
1	What's driving the need for improvement?
2	
3	
4	
5	

Measurable Target Condition	
1	Reduce <defined metric> from X to Y (Z% improvement).
2	Increase <defined metric> from X to Y (Z% improvement).
3	
4	
5	

Benefits to Customers	
1	How will internal and / or external customers benefit
2	as a result of improvements to the VS?
3	
4	
5	

Benefits to Business	
1	What other benefits will the business or internal customers realize
2	as a result of improvements to the VSM?
3	
4	

Mapping Team			
	Function	Name	Contact Information
1	Leadership-heavy		
2			
3			
4			
5			
6			
7			
8			
9			
10			

On-Call Support			
	Function	Name	Contact Information
1	SMEs that may not be needed full time		
2			
3			
4			

Agreement			
	Executive Sponsor	Value Stream Champion	Facilitator
	Signature:	Signature:	Signature:
	Date:	Date:	Date:

*Reprinted with permission from *Value Stream Mapping: How to visualize work and align leadership for organizational transformation*, by Karen Martin & Mike Osterling, 2013, New York: McGraw-Hill. Copyright [2013] by Karen Martin.

5.3.1.1 Scope

A clearly defined scope will ensure the focus is on the right processes in a value stream, because valuable time is spent on improving those processes. In my value stream mapping process, I have mapped three value streams: the whole research study, literature articles reading, and reporting progress meetings. Each has a different scope. The whole research study has the widest scope, including topic selection, committee members' selection, proposal defense, and thesis writing thesis. It provides a holistic view of the research study. The scope is to finish the whole research study. In contrast, the other two value streams' scopes are limited to two processes, i.e. literature reading and progress meetings, within the whole value stream. The scopes of these two value streams are to finish certain processes within the whole value stream. Figure 11 shows the relationships of the three value streams.

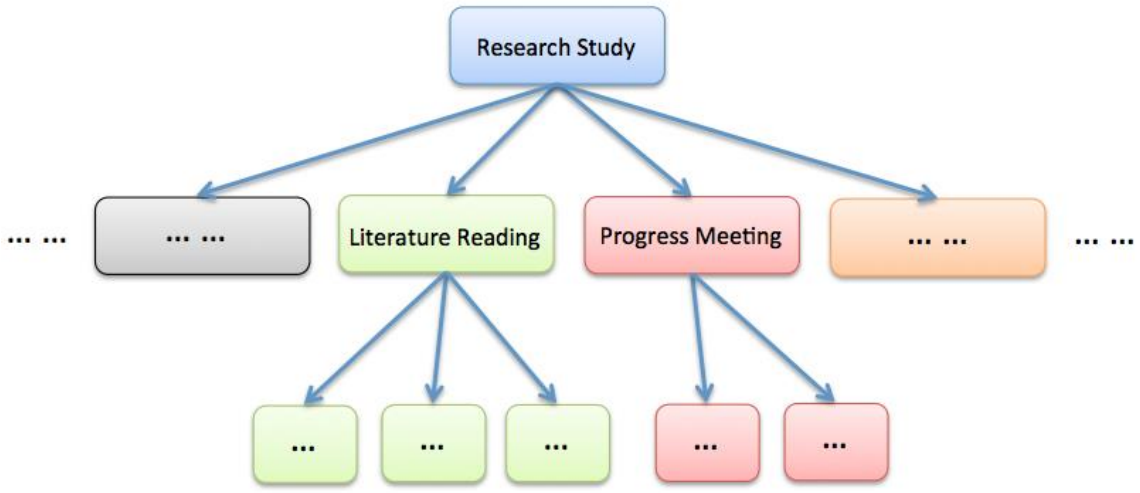

Figure 11. Value Stream Hierarchy

(1) Value Stream

Under different scopes, there are different value streams that deliver different values for different purposes. For my research study, the target is the final thesis, and activities that do not contribute to the thesis should be eliminated or minimized. The value stream of my progress meetings is the activities I need to do in order to receive instructions for further research work. A summary of one paper is the final product of my literature reading, thus the value stream includes activities I need to do in order to finish this summary.

Clearly understanding each value stream will be helpful in identifying value-adding activities, non-value-adding activities or non-value-adding but necessary activities.

(2) Specific Conditions

Specific conditions include the specific circumstances included in or excluded from the mapping activity. In the value stream mapping of my research study, only types of work are included, e.g. change committee member, report progress. How to accomplish those tasks is excluded.

(3) Trigger

The trigger is the action that initiates the value stream. In my progress meeting value stream, the trigger will be a discussion with my thesis chair after I have finished certain work on my research and need instructions for new work.

(4) First step, last step

This defines the start and ending activities in a value stream, and sets the range of activities that are needed to deliver the value.

(5) Limitations and boundaries

This section specifies the boundaries or certain conditions within which the work needs to be operated and the limitations the work might have. The boundary for my reporting progress might be that I must schedule with my thesis chair for face-to-face meetings. Although this might add lead time in the processes, for a better result, i.e. more value delivered, I would not choose to communicate with him by E-mail or phone. The limitation for my research study value stream mapping might be that the time spent on activities is hard to calculate and record, since they each last a long time and I can just estimate the time spent on each activity. Another limitation is because I can only read in English and Chinese. I cannot read literature that might be useful in other languages.

5.3.1.2 Current State Problems and Needs

This section includes the problems the value stream faces and the driving force for improvement. For my research study, since it is the first time I have undertaken graduate level research, the problem is I do not have a clear understanding of the research process. As a result, some activities in my value stream are not adding value to my research process; I even needed to redo certain activities. The need for improvement is to develop a holistic view of how the research should be done. I can learn from the experience and apply it in future research studies.

5.3.1.3 Measurable Target Condition

This part of the charter shows how one plans to improve by providing measurable improvement, such as the percentage of improvement. For example, in my

literature reading process, my target is to increase efficiency to shorten the time by 30% than previous.

5.3.1.4 Benefits to Customers and Benefits to Business

Similar to the need for improvement, this shows the benefit from the improvement. In my research study, the "customers" are my committee members to whom I must "deliver" my thesis. The "business" is my ability to do a research study. Thus, from my perspective, the benefit of my value stream mapping process to my "customer" may include two aspects: first is better evaluation of my work during the research; second is my value stream maps might be used as a guideline for their future students who have no experience in doing research. It will help other students gain an overall view of the whole process and the approximate time needed so that they can better plan their research study. The benefit to my "business" will be the improvement of my ability in doing research.

5.3.1.5 Accountable Parties

For the best success with value stream improvement, there must be a support team. In a business environment, there will be executive sponsor, facilitator, logistics coordinator, briefing attendees, etc. In my value stream mapping process, the support team is made up of my committee members and my classmates who gave me instructions and advice to help me in the research study.

5.4 Mapping the Current State

After the planning process, the next and the most vital step in value stream mapping is mapping the current state. The current state value stream map shows how the

value stream is performing; a deep understanding of the current state is an important step in making improvements.

As mentioned, I have mapped out three value streams during my research project: write thesis, read literature and report progress. Reading literature and reporting progress are support value streams of the thesis writing process.

5.4.1 First Value Stream Walk

The first step in creating the current state is walking the value stream. In my case, it is an individual work and many of the processes are information exchange rather than tasks that are physically done. Thus, in the value stream walk step, I tried to "walk" the activities I had completed by reviewing my schedules, notes, E-mails and other records.

5.4.2 Map Layout

After the first walk, the activities are listed. Then I started to sketch on an 11×17 inch paper. Activities are put in process blocks that will form the value stream. In the process blocks, there is a description of the activities in brief words and in verb-plus-noun format. In my Research Study value stream map, there is a branch of activities that were happening simultaneously with the mainstream activities.

5.4.3 Second Walk

In the second walk, I checked for any conflict in the process blocks and I gained a deeper understanding of how the work is currently performed.

5.4.4 Metrics for Each Process Block

There are many metrics for each process block in a value stream map, e.g. process time (PT), lead time (LT), percent complete and accurate (%C&A), batch size,

work-in-process (WIP), etc., in other contexts. Many of the metrics are not applicable in my value stream mapping process. Thus, instead of struggling to find inaccurate and meaningless data, I decided to include only PT and LT in my value stream mapping processes. Process time is the time it takes to finish the process task from an input into an output for the work. Lead time is the elapsed time period from when the work is made available until it is finished and is available for the next step. Unlike tasks that can be performed within a short period of time, my research study lasted for nearly one year. As with many processes in my research study value stream mapping, the time is difficult to measure due to the quantity of work or my work efficiency. Thus, I simply estimated the average time I spent on each activity. I was able to identify the waste in my work without being too entangled with the time difference.

5.4.5 Information Flow

Value stream mapping is an effective tool in visualizing information that flows through the activities and the media in which the information is being processed.

5.4.6 Current State Maps

The following are the three current state maps drawn for this research: Research Study Current State Map, Progress Meeting Current State Map and Literature Reading Current State Map. The Research Study is the process needed for me to complete a master's degree, and this thesis is the final deliverable to my "customer," my committee. The Research Study Value Stream Map enables my committee to evaluate my work process and my ability to apply what I have learned into practice. Also, it is a good way to improve myself. The Progress Meeting Map and the Literature Reading Map are two

support value streams within the main Research Study value stream. They do not provide direct output to the thesis, but they are value-enabling value streams in the whole process. In addition, they are the two most repetitive tasks in my research study process, upon which I can make improvements for future work.

Following are the Research Study Current State Map, Progress Meeting Current State Map and Literature Reading Current State Map.

Research Study
Current State Map

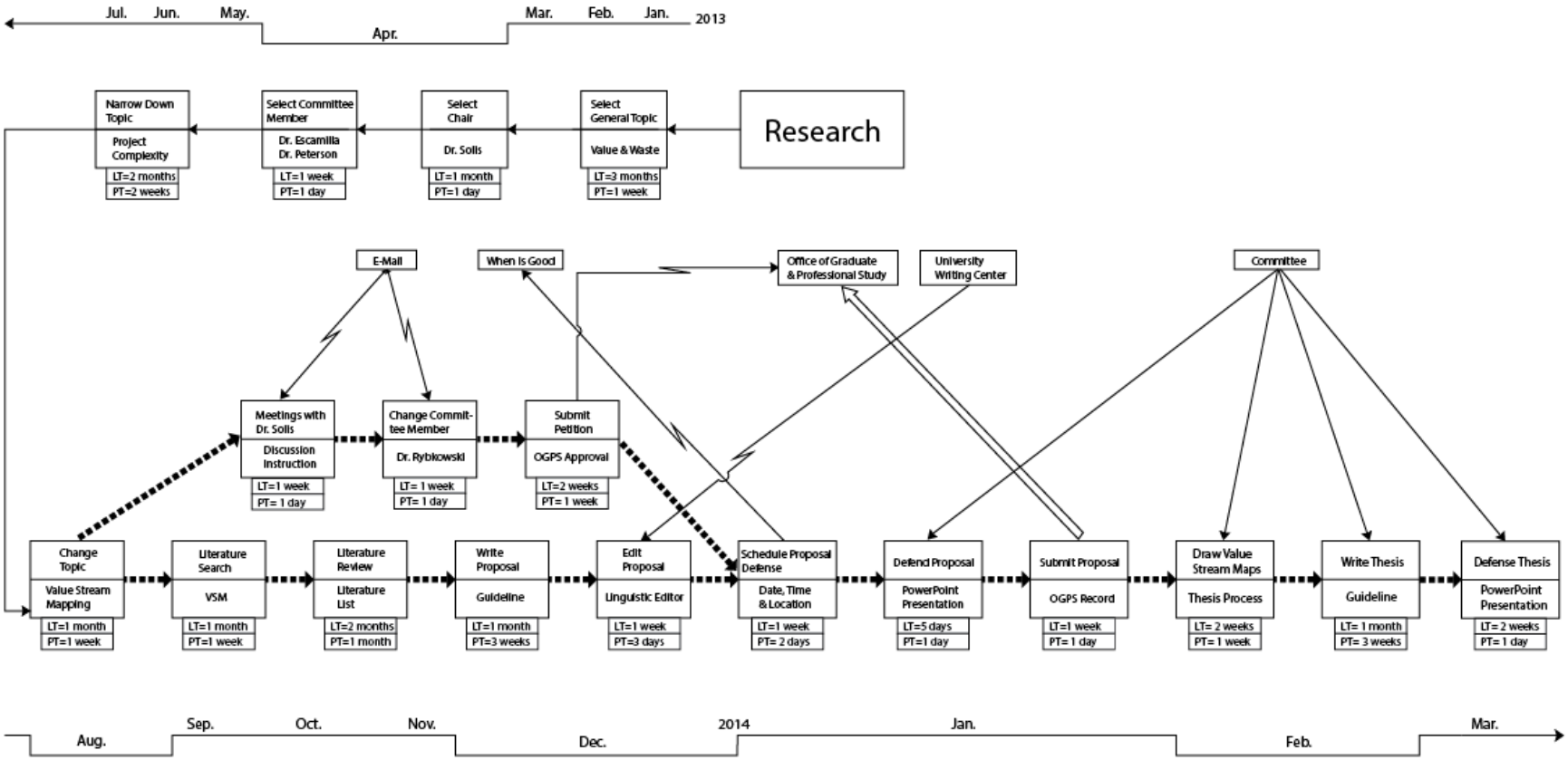

Figure 12. Research Study Current State Map

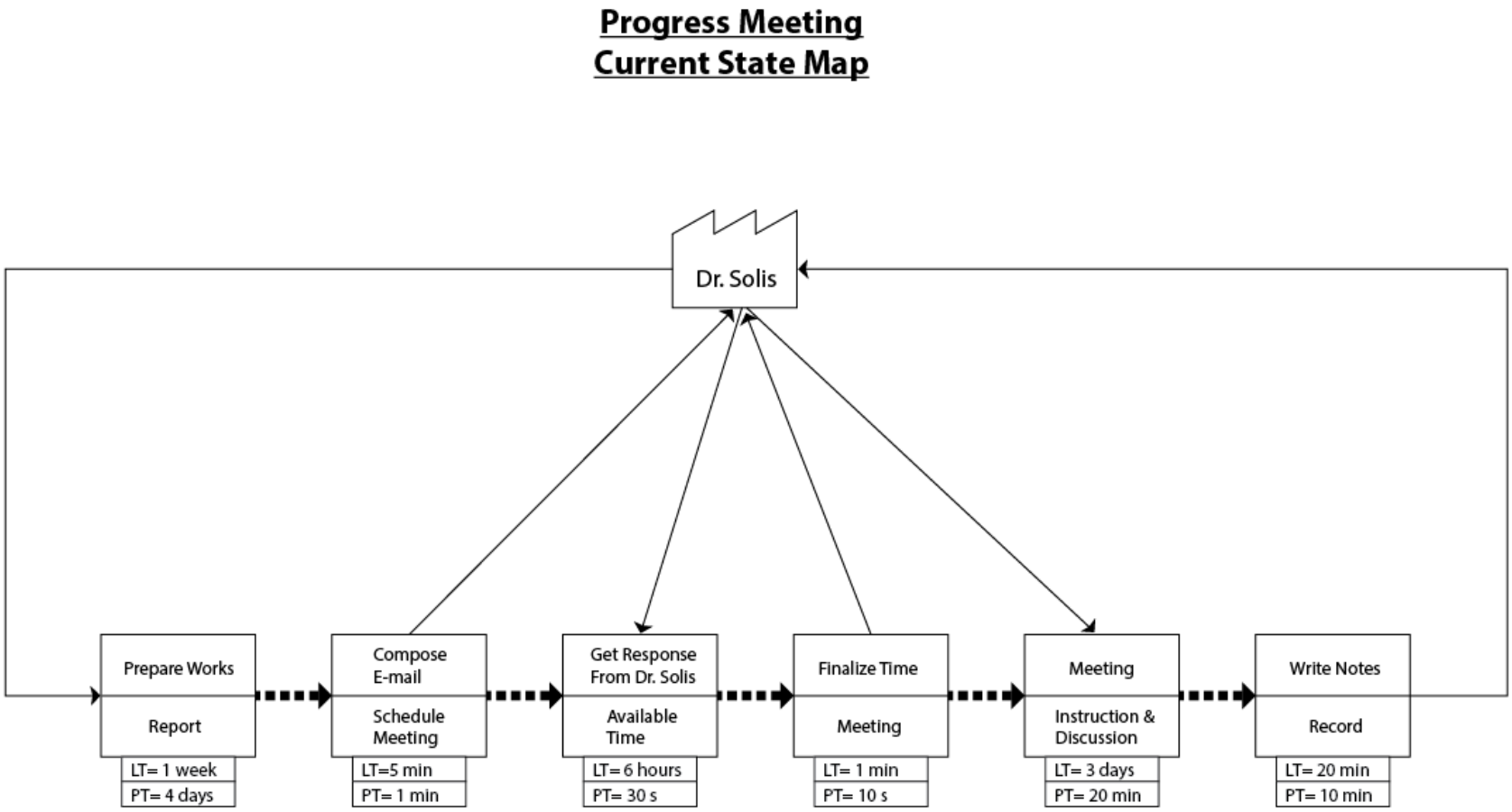

Figure 13. Progress Meeting Current State Map

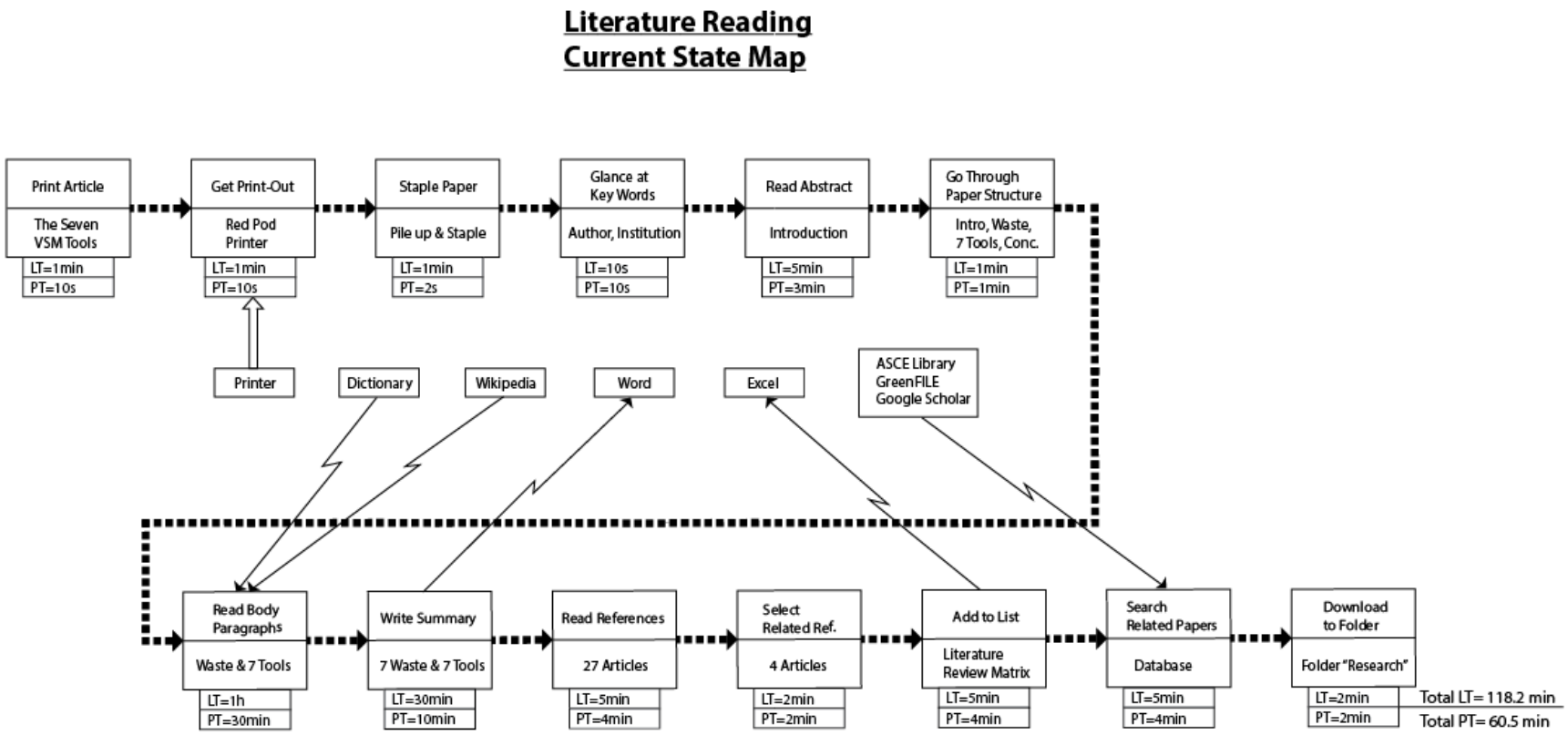

Figure 14. Literature Reading Current State Map

5.5 Identifying Waste and Possible Solutions

The next step is analyzing the current state maps to identify any waste in the value stream. The waste in my work process is defined as processes that are not adding value to my final deliverable.

5.5.1 Waste in the Research Study Process

In the value stream map of the research study process, I included the rough time line of my work following the Office of Graduate and Professional Studies Calendar. I realize that although I am able to finish my research on time, I am working right against the deadlines for the two defenses. If I had planned ahead, I would have shortened the lead time in finishing the thesis and been more efficient. Another waste I found was changing one committee member. Having the new committee member on board was quite helpful in finishing my thesis, however, the change could be considered a waste. I needed to submit petitions and wait for approval from different committee members, the department and the Office of Graduate Studies. I could have eliminated the waste by having that faculty member on board at the beginning if I had a clearer vision about my research.

5.5.2 Waste in the Progress Meeting Process

Having meetings with my thesis chair is one of the very important parts in my research study. He gave me helpful advice and direction about how to do a research study step by step. When I had new ideas or questions, I would set up a meeting with him. However, by analyzing the current state map, I found the waste was the lead time between when I finished a task and the meeting with my chair. Every time I finished my

work, I scheduled a meeting. However, the time for me to finish each task was variable, thus the lead time was inevitable. The improvement I suggest for this issue is setting recurrent meeting times with my chair, e.g. once a week. This would help avoid the lead time for meetings and impel me to finish my work on time. This is one of the lean principles of creating a continuous flow of work.

5.5.3 Waste in the Literature Reading Process

My research is based on a literature review, so literature reading is the one of the most important parts. In the literature reading current state map, I chose a 15-page paper, which is the average length among the articles, recorded the time I spent on each part and drew the current state map. I wrote summaries when I finished reading a paper for future review. In my mapping process, I found the waste associated with writing the summary. Usually I would write the summary after I finished the entire paper; however, sometimes I already forgot the previous content in the paper, so I had to go back to review. In this mapping process, the reviewing time was 20 minutes, which is two thirds of the total summary time. This can be viewed as an example of "batching" in Lean context, which leads to more work-in-process (WIP) and is less efficient. The improvement I put forth for this waste is to summarize each part once finished, whereby I could save time and be more accurate in summarizing.

5.6 Future State Maps

After analyzing the current state maps, I identified the waste in each value stream and came up with possible solutions. Based on the analysis, I created future state maps with the improvements. Those future state maps will be my guidelines for my future

research studies. In the Research Study Future State Map, I included the timeline that follows my thesis chair's enlightening suggestions for students in doing research. In the Progress Meeting Future State Map, the improvement is to set a recurrent meeting time. As a result, the processes should become very simple and the lead time will be minimized. The improvement in literature reading is to read electronic versions instead of printed copies to eliminate waste. The most important is to write summaries while reading, which should help in minimizing the time for reviewing the previous reading. Also I will be able to write down the insightful ideas while reading.

The future state maps represent the direction toward which I want to work. By doing value stream mapping to visualize my research process, I identified the waste in my work, which I completely neglected before mapping. Although it is a practice, I regard this as a meaningful evaluation that not only helped me improve my work processes but also provided me a deeper understanding of the powerful lean tool that I will be able to apply to my future work.

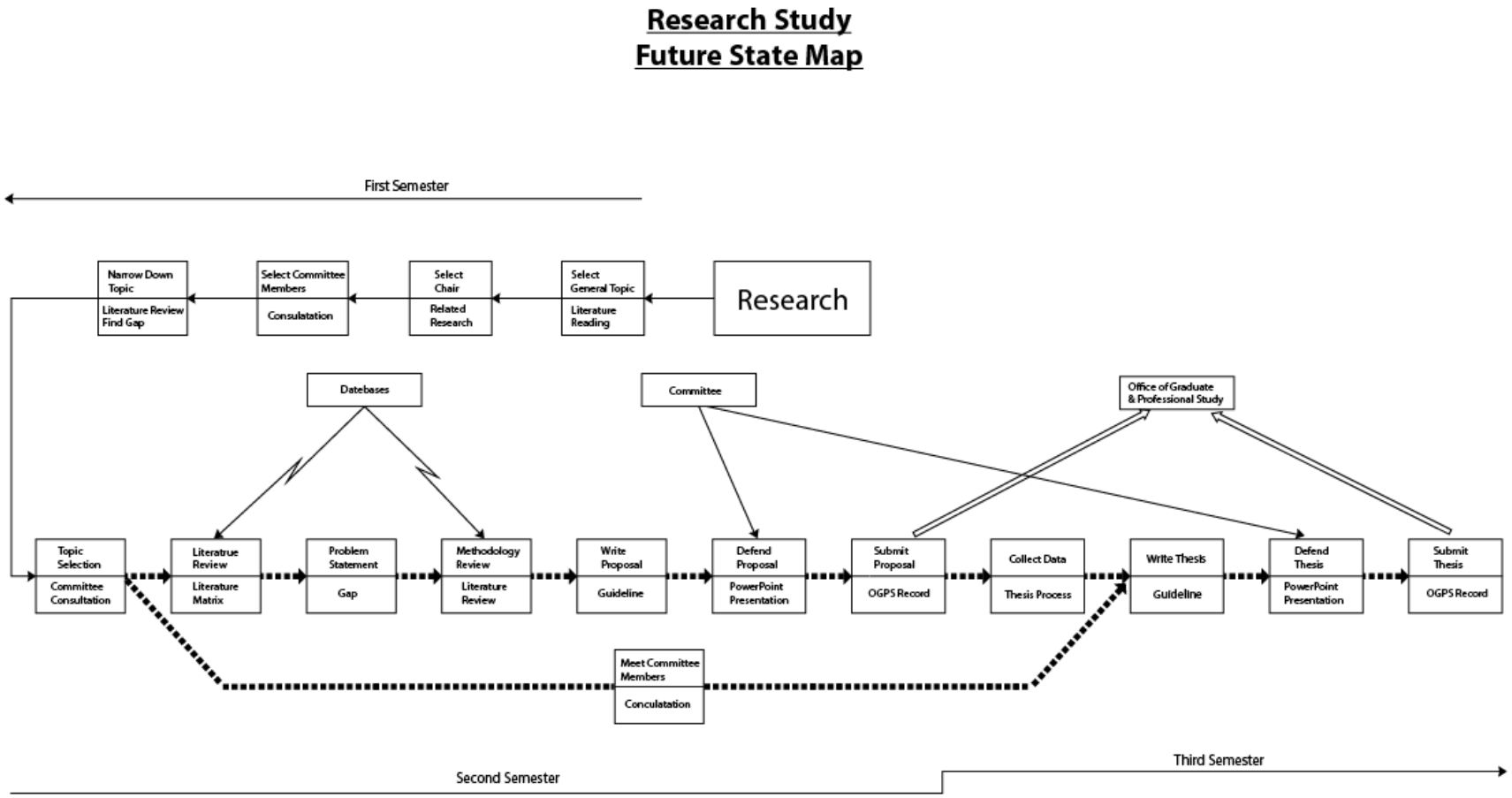

Figure 15. Research Study Future State Map

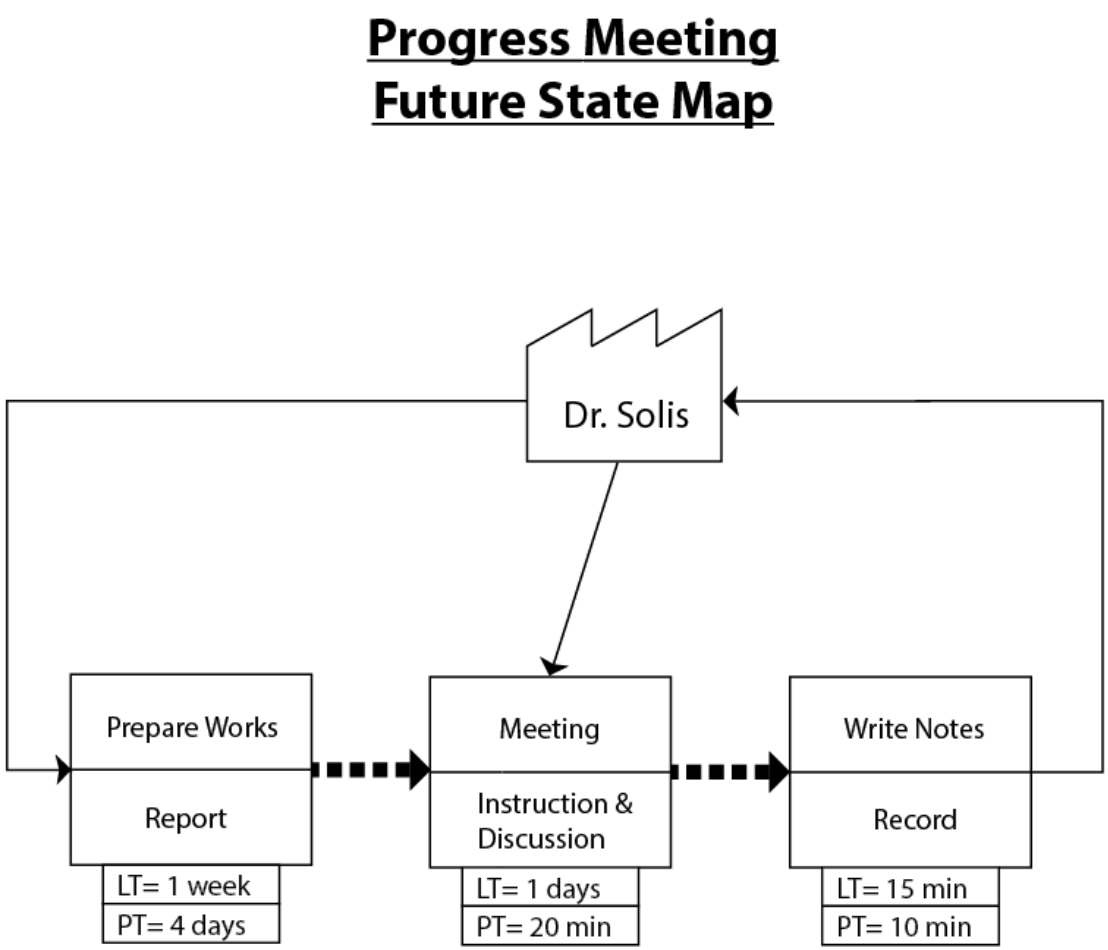

Figure 16. Progress Meeting Future State Map

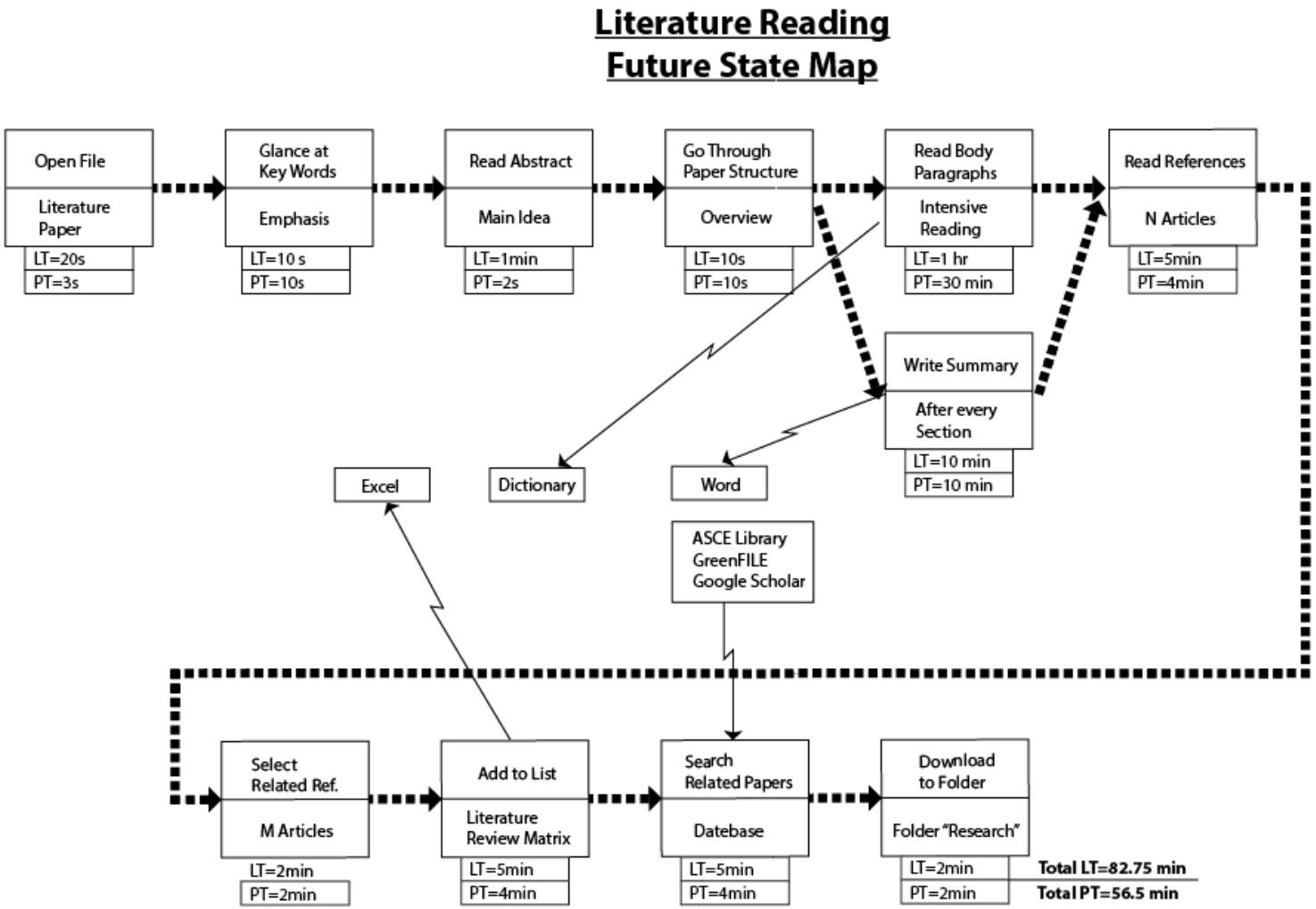

Figure 17. Literature Reading Future State Map

5.7 Summary

By applying value stream mapping to practice, I realized the benefits the tool brought to my work. I identified embedded waste, which had been neglected before in the working process. In the future state of literature reading value stream, the lead time is reduced from 118 minutes to 82 minutes, the process time is reduced from 60 minutes to 56 minutes, and the efficiency of this process is increased. Through the practice, I realized the advantages that value stream mapping has over other control tools, such as Critical Path Models (CPM). Waste activities such as waiting, redoing, and batching are generally not modeled by CPM, however, in value stream mapping those wastes can be easily identified.